CHAPTER 4

REDUCTION GEARS AND RELATED EQUIPMENT

This chapter contains information on the operation, care and maintenance of reduction gears and related equipment found on Navy ships. All EN1s and ENCs must be familiar with the design and construction details of naval reduction gears and related equipment. When more detailed information is needed, refer to the manufacturer's technical manual.

REDUCTION GEARS

The main reduction gears are the largest and most expensive single units of machinery found in the engineering department. When the main reduction gears are installed properly and are operated properly they give years of satisfactory service. However, when casualties occur to the main reduction gears they put any ship out of operation or force it to operate at reduced speed. Main reduction gear repairs are very costly. Usually they must be accomplished by a shipyard.

FACTORS AFFECTING GEAR OPERATION

Proper lubrication is essential for the efficient operation of reduction gears. This includes supplying the proper amount of oil to the gears and bearings, and keeping the oil clean and at the proper temperature. All abnormal noises and vibrations must be investigated and corrective action must be taken immediately. Gears and bearings must be inspected in accordance with current instructions issued by NAVSEA, the type commander, or other proper authority.

Lubrication of Gears and Bearings

The correct quantity and quality of lubricating oil must be available at all times in the main sump. This oil must be clean and it must be supplied to the gears and bearings at the pressure specified by the manufacturer. In order to supply the proper quantity of oil, several conditions must be met. The lubricating oil pump must deliver the proper discharge pressure, and all relief valves in the lubricating system must be set to function at their designed pressure. Too small a quantity of oil will cause the bearing to run hot. On the other hand if too much oil is delivered to the bearing, the excessive pressure will cause the oil to leak at the seal rings, and may also cause the bearing to overheat.

Lubricating oil must reach the bearing at the proper temperature. If the oil is too cold, there will be insufficient oil flow. If the oil supply is too hot, some lubricating capacity is lost. For most main reduction gears, the normal temperature of oil leaving the lube oil cooler should be between 120°F and 130°F. For full power operation, the temperature of the oil leaving the bearings should be between 140°F and 160°F. The maximum temperature rise of oil passing through any gear or bearing, under any operating condition, should not exceed 50°F, and the final temperature of the oil leaving the gear or bearing should not exceed 180°F. Temperature rise and limit may be monitored by a thermometer or by a resistance temperature element installed where the oil is discharged from the bearings.

Cleanliness of lubricating oil cannot be overstressed. The oil must be free from such impurities as water, grit, metal, and dirt. Particular care must be taken to remove metal flakes and dirt when new gears or bearings are wearing in or after they have been opened for inspection. Lint or dirt, if left in the system, may clog the oil spray nozzles. The spray nozzle passages must be open at all times. Spray nozzles should not be altered without proper authorization.

Although the lubricating oil strainers perform satisfactorily under normal operating conditions, they cannot trap particles of metal and dirt which are fine enough to pass through the mesh. These fine particles can become embedded in the bearing metal and cause wear on the bearings and journals. These fine abrasive particles passing through the gear teeth act like a lapping compound and remove metal from the teeth.

EFFECTS OF WATER AND ACID IN OIL.—Water in the oil is extremely harmful. Even small amounts soon cause pitting and corrosion of the teeth. Acid can cause even more serious problems. The oil must be tested frequently for water, and periodic tests should be made for acid content. Immediate corrective measures must be taken when saltwater is found in the reduction gear lubricating oil system.

Occasionally gross contamination of the oil by saltwater occurs when a cooler leaks or when leaks develop in a sump. The immediate location and sealing of the leak is not enough. Additional steps must be taken to remove the contaminated oil from all steel parts. Several instances are known when, because such treatment was postponed—sometimes for a week or less—gears, journals, and couplings became so badly corroded and pitted that it was necessary to remove the gears and recondition the teeth and journals. Saltwater contamination of the lubricating oil may also cause bearing burnout.

Water, in small amounts, is always present within the lubrication system as a result of condensation. Air which enters the units contains moisture. This moisture condenses into water when it strikes a cooler surface and subsequently mixes with the oil. The water displaces the oil from the metal surfaces and causes rusting. Water mixed with oil also reduces the lubricating value of the oil itself.

When the main engines are secured, the oil should be circulated until the temperature of the oil and that of the reduction gear casing approximate the engineroom temperature. While the oil is being circulated, the cooler should be operated and the gear should be jacked continuously. The purifier should also be operated to renovate the oil while the oil is being circulated and after the oil circulation is stopped until water is no longer discharged from the purifier. This procedure eliminates condensation from the interior of the main reduction gear casing and reduces rusting in the upper gear case and gears.

Generally, lubricating oil will be maintained in good condition if proper use is made of the purifier and settling tanks. However, if the purifier does not operate satisfactorily and does not have the correct water seal, it will not separate the water from the oil. You can check for the presence of water by taking small samples of oil in bottles, and allowing the samples to settle. These samples should be taken from a low point in the lube oil system.

Samples of lubricating oil should be tested at every opportunity for acid, water, and sediment content at a naval shipyard (or other similar activity). With continuous use, lube oil increases in acidity, and free fatty acids form a mineral soap which reacts with the oil to form an emulsion. As the oil emulsifies, it loses its lubricating quality. Once the oil has emulsified, the removal of water and other impurities becomes increasingly difficult. When the formation of a proper oil film is rendered impossible, the oil must be renovated.

Sometimes, when a ship from the reserve fleet is placed back in commission, the rust preventive compound is not removed completely. The residue of this compound may cause serious emulsification of the lubricating oil. Operating with emulsified oil may result in damage to the bearings or the reduction gears. Since it is extremely difficult aboard ship to destroy emulsions by heating, settling, and centrifuging, you must make sure that emulsions do not occur. At the first indication of an emulsion, the plant should be stopped and the oil renovated.

MAINTAINING FOR PROPER OIL LEVEL.—It is of extreme importance that the quantity of oil in the sump be maintained within the prescribed maximum and minimum levels. Too much oil as well as too little oil in the sump can lead to trouble. If the oil level is above the prescribed maximum and the bull gear runs in the oil, the oil foams and heats as a result of the "churning" action. If the oil level is below the prescribed minimum, it may lead to a low lube oil casualty such as a damaged bearing or gears.

In gear installations where the sump tank extends'up around the bull gear, and the normal oil level is above the bottom of the gear, an oil-excluding pan (sheet metal shield) is fitted under the lower part of the gear to prevent its running in the sump oil. Under normal conditions, the bull gear comes in contact with only a small quantity of oil. The oil which tends to fill the pan is swept out by the gear and is drained back to the sump.

When there is too much oil in the sump, the engines must be slowed or stopped until the excess oil can be removed and normal conditions restored. Routine checks should be made to see that the lubricating oil is maintained at the proper level. Any sudden loss or gain in the amount of oil should immediately be investigated.

Unusual Noises

A properly operating gear has a definite sound which the experienced engine operator can easily recognize. The operator should be familiar with the sounds of the gears aboard the ship during normal operation and at different speeds and under various operating conditions.

Often the readings of lube oil pressures and temperatures may help in determining the reason(s) for abnormal sounds. A burned-out pinion bearing or main thrust bearing may be indicated by a rapid rise in oil temperature for the individual bearing. A noise may indicate misalignment, improper meshing of the gear teeth, or gear tooth damage.

When there is either a burned-out bearing or trouble with the gear teeth, the main propeller shaft should immediately be stopped, locked, and inspected to determine the cause of the abnormal sound or noise. The trouble should be remedied before the reduction gear is placed back in operation.

In some cases, conditions of a minor nature may cause unusual noises in a reduction gear which is otherwise operating satisfactorily. When an investigation reveals the cause of the noise to be minor, the gear should be operated cautiously and under close observation by experienced personnel. A more thorough investigation should be made, as soon as practicable, to determine the cause of the unusual noise. Upon discovery of the trouble, appropriate action should be taken to remedy the condition.

Vibration

If the main reduction gear begins to vibrate, a complete investigation should be made, preferably by a naval shipyard. Vibrations may be caused by bent shafts, damaged propellers, misalignment between prime mover and gear, a worn out bearing, or coupling, or an improper balance in the gear train. When these units are built, the gear wheels are carefully balanced (both statically and dynamically). Later any unbalance in the gears is manifested either by unusual vibration and noise, or by unusual wear of the bearings.

When a ship has been damaged, vibration of the main reduction gear may result from misalignment of the engine and the main shafting as well as from misalignment of the engine and the main gear foundation.

When the vibration occurs within the main reduction gear, trouble or damage to the propeller should be one of the first things to consider. The vulnerable position of propellers makes them more liable to damage than any other part of the main plant. Bent or broken propeller blading and propellers fouled with line and steel cable may transmit vibration to the main reduction gear.

MAINTENANCE OF REDUCTION GEARS

Under normal conditions, all repairs and major maintenance on main reduction gears should be accomplished by a naval shipyard. However, when the services of a shipyard are not available, emergency repairs should be accomplished (where possible) either by a repair ship or at an advanced base. Minor inspections, tests, and repairs should be accomplished by the ship's force.

It is of utmost importance that the ship retain a complete record of the reduction gears from the time of commissioning. Complete installation data, furnished by the contractor, should be entered in prescribed records by the ship's engineering personnel when the ship is at the contractor's yard. They should include the crown thickness readings and the clearances of the original bearings, the thrust settings and clearances, and the backlash and root clearances for gear and pinion teeth. It is essential to have this information available at the time when the alignment must be checked.

All repairs, adjustments, readings, and casualties should be reported in accordance with 3-M system procedures. All original bearing data, as well as all additional bearing measurements, should be entered in appropriate records.

The manufacturer's technical manual, which gives detailed information regarding repairs to be made to reduction gears, is furnished to each ship.

Special tools and equipment are normally provided on board ship for (1) lifting some reduction gear covers, (2) handling the gear elements when removing or replacing their bearings, (3) making the required measurements, and (4) rebabbitting bearings.

These special tools and equipment should be available aboard ship in case repairs have to be made by repair ships or at advanced bases. Bridge gages are no longer used to check bearing wear of the main reduction gears. When bearing wear must be checked, the crown thickness method is used.

A bearing shell consists of a pressure-bearing half and a nonpressure-bearing half. The nonpressure-bearing half has a radial scribe line at one end of the geometric center. The pressure-bearing half of every main reduction gear shell has three radial scribe lines on each end of the bearing shell (figure 4-1). As you can see one of these scribe lines is located at the geometric center of the shell and the remaining lines intersect the center scribe line at a 45° angle.

The crown thickness of each shell at these points should be measured with a micrometer at a prescribed distance from the end of the shell. These measurements should be recorded during the initial alignment and should be permanently marked adjacent to each scribe line.

The amount of bearing clearance should not be allowed to become too great to cause incorrect tooth contact. The designed clearances for bearings are given in the manufacturer's technical manual. These clearances are also shown on the blueprints for the main reduction gears.

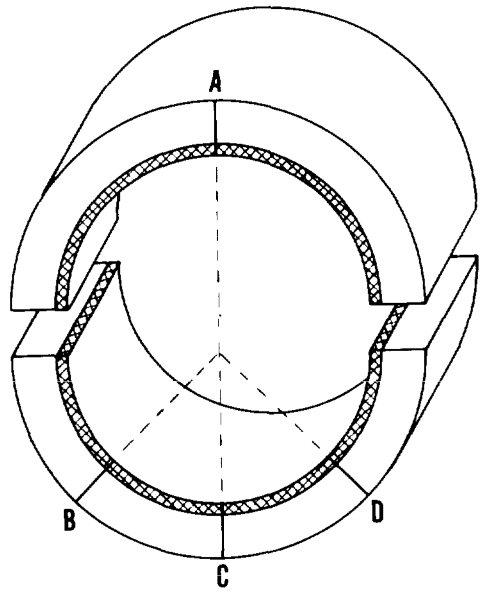

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Figure 4-1.—Scribe lines used in measuring the crown thickness of reduction gear bearings.

On a multishaft ship, if a main reduction gear bearing is wiped, the preferred procedure (if practicable) is to secure the shaft and the reduction gear until the units can be inspected and repaired by a repair activity.

A glance at figure 4-2 will indicate why the replacement of a bearing in a main reduction gear would be a major undertaking for the ship's force. However, emergency conditions may require action by the ship's force. When such action is to be taken, a number of factors must be taken into consideration before repairs are attempted.

The first factor to consider would be whether or not to attempt the repair work.

The EN1 or the ENC must study the manufacturer's instructions and the blueprints for the reduction gear, so as to have a clear understanding of the constructions details and the repair procedures and to be able to decide whether or not the work should be done by the ship's force. Other factors which must be considered are the location

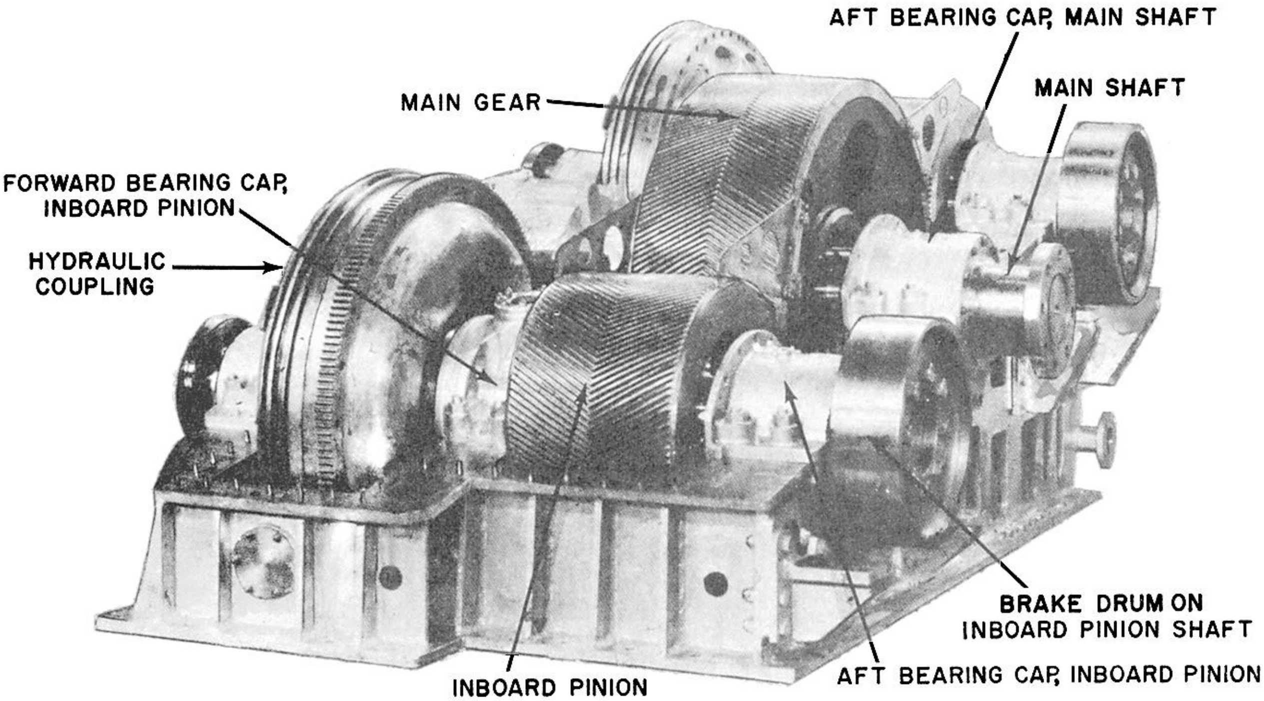

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Figure 4-2.—Starboard gear unit with cover removed—view from aft and inboard.

of the ship, the availability of Navy repair activities, and the operational schedule of the ship.

CAUTION: No portion of the gear casing or its access openings, plugs, piping, or attached fixtures shall be dismantled or removed without the specific authorization of the ship's engineer officer.

Refer to the gear shown in figure 4-2 during the following discussion. Assume that the after bearing for the inboard pinion has been wiped because of an obstructed oil passageway.

When making repairs to this unit, ensure the propeller shaft is locked rigid and the lubricating oil is pumped from the sump BEFORE the bearing cap is disturbed. For the physical security of main reduction gears refer to Naval Ship's Technical Manual chapter 9420 and current ships instructions. After removing the bearing cap, remove and inspect the upper half of the bearing. Then, with the aid of a special jack, roll out the lower half of the bearing. The function of the jack is to relieve the weight from the lower half of the bearing and to properly support the rotating elements when the journal bearings are removed.

The journal surface of the shaft and all oil passages (nozzles) should be carefully inspected and cleaned. The new bearing to be used to replace the wiped one should also be cleaned and inspected. Its crown thickness, as measured at the factory, is stamped on the new bearing. The measurements of the new bearing should be compared with those of the original bearing and with the specifications in the manufacturer's instructions.

After ensuring that the new bearing is well oiled, the lower half of the bearing can be rolled into place and the jack removed. Then the upper half is placed in position. Be sure that the bearing and its dowel are in the required position, and in accordance with the manufacturer's instructions. Afterwards, the bearing cap can be lowered into position and securely bolted down.

It is possible that the forward bearing for the inboard pinion is also damaged as a result of excessive wear. When one pinion bearing fails, that end of the shaft will tend to move away from the bull gear; consequently, an abnormal load will be placed on the other pinion bearing. For this reason, the other pinion bearing should also be opened and inspected, and checked with a micrometer, using the crown thickness method. All readings should compare with the readings listed in the manufacturer's instructions. If excessive wear is indicated, the bearing should be replaced with a new one. If no wear of the opposite pinion bearing is indicated, then the forward bearing can be reassembled.

The condition of the bearings depends a great deal upon the type of casualty that has occurred. When the casualty is due to a loss of lubricating oil, the pinion bearings must be checked first. If these bearings are in good condition, it may be assumed that the bull gear shaft bearings are also in satisfactory condition. However, after a bearing casualty has been corrected, a close watch should be maintained on all bearings.

Remember that when the reduction gear is opened, every precaution should be taken to keep out dirt and foreign matter and that the repair personnel should remove all loose articles from their clothing. Again, before closing the reduction gear, a careful inspection should be made to see that the inside of the gear is free of all dirt, foreign matter, and misplaced tools.

Gear Teeth

New gears or gears which have been realigned should be given a wearing-in run at low power before being subjected to the maximum tooth pressure of full power.

For the proper operation of the gears, it is essential that the tooth contact (or total tooth pressure) be uniformly distributed over the total area of the tooth faces. This is accomplished by accurate alignment and adherence to designed clearances. Gear tooth contact is verified by the application of Dkem to the gear teeth and by jacking the gears. Then the gears are inspected to check for the Dkem impressions.

The designed center-to-center distance of the axes of the rotating elements should be maintained as accurate as practicable. In all cases the axes of pinions and gear shafts must be parallel. Nonparallel shafts concentrate the load in one end of a helix. This situation may cause flaking, galling, pitting, featheredge on teeth, deformation of tooth contour, or breakage of tooth ends.

The designed TOOTH CONTOUR must also be maintained. If the contour is destroyed, a rubbing contact will occur with consequent danger of abrasion.

If proper tooth contact is obtained when the gears are installed, there will not be much trouble as far as the WEAR OF TEETH is concerned. Excessive wear cannot take place unless there is metallic contact, and metallic contact will not occur if adequate lubrication is provided. An adequate supply of lubricating oil at all times, proper cleanliness, and inspection for scores will prevent the wearing of teeth.

If, after all precautions have been taken, the lubricating oil supply should fail and the TEETH DO BECOME SCORED, the gears must be thoroughly overhauled by a naval shipyard, as soon as possible.

During the first few months that reduction gears are in service, PITTING may occur, particularly along the pitch line. Although slight pitting does not affect the operation of the gears, care must be taken to see that no flakes of metal are allowed to remain in the oiling system.

Play between the surfaces of the teeth in mesh on the pitch circle is known as BACKLASH. It increases as the teeth wear out. However, backlash can increase considerably without causing any trouble.

ROOT CLEARANCE.—The designed root clearance with gear and pinion operating on their designed centers can be obtained from the manufacturer's drawing or blueprint. The actual clearance can be found by taking leads or by inserting a long feeler gage or a wedge gage. This clearance should check with the designed clearances. When the root clearance is considerably different at the two ends, the pinion and gear shaft are not parallel. Some tolerance is permitted, provided that there is still sufficient backlash and that the teeth are not meshed so closely that lubrication is adversely affected.

ALIGNMENT OF GEAR TEETH.—When the gear and the pinion are parallel (axes of the two shafts are in the same plane and equally distant from each other), the gear train is aligned. In service the best indication of proper alignment is good tooth contact and quiet operation.

The length of tooth contact across the face of the pinions and gears is the criterion for satisfactory alignment of reduction gears. To static check the length of tooth contact, coat about 5 to 10 teeth with either Prussian blue or red lead, then roll the gears together with sufficient torque to cause contact between the meshing teeth and force the journals into the ahead reaction position in their bearings. After you determine the tooth contact, remove all the coating to prevent possible contamination of the lubricating oil. If tooth contact is to be checked under operating conditions, coat the teeth with red or blue Dyken or with copper sulphate.

SPOTTING GEAR TEETH.—All abnormal conditions which may be revealed by operational sounds or by inspections should be corrected as soon as possible. Rough gear teeth surfaces, resulting from the passage of foreign objects through the teeth, should be stoned smooth. If the deterioration of a tooth surface cannot be traced directly to a foreign object, give special attention to lubrication and to the condition of the bearings. Also consider the possibility that a change in the supporting structure may have disturbed the parallelism of the rotors.

Spotting reduction gear teeth is done first by coating the teeth with Prussian blue and then by jacking the gear in its ahead direction of rotation. As the gear teeth come in contact with the marked pinion teeth, an impression is left on the high part of each gear tooth. Rotate the gear about 1/4 of a turn to a convenient position for stoning. Then remove all the high spots indicated by the marking with a small handstone. Normally, it will be necessary to replace the bluing on the pinion teeth repeatedly, since if the bluing is applied too heavily you may obtain false impressions on the gear teeth.

A satisfactory tooth contact is obtained when at least 80% of the axial length of the working face of each tooth is in contact and distributed over approximately 100% of the face width.

Remember that the stoning of gears is useful only to remove a local hump or deformation, not to remove deep pitting or galling.

Main Thrust Bearings

A ship is moved through the water by an axial thrust that is developed by the propeller and transmitted to the ship's structure. This axial thrust is transmitted by the shaft through a thrust bearing which is located either at the forward end or at the after end of the main reduction bull gear or in the propeller line shafting aft of the gear. Pivoted-segmental shoe bearings (Kingsbury type) utilize a wedge-shaped film of oil in their operation. The source of lubricating oil for thrust bearings depends on the location of the bearings. In some installations oil is provided by the same system which furnishes oil to the reduction gears. In other installations, a separate lubricating system is provided.

Kingsbury-type thrust bearings consist of a collar mounted on the shaft and revolving between one or more sets of babbitt-faced segmental shoes. The backs of these shoes rest against round hardened steel pivots which permit the shoes to assume a tilt and change their angle with respect to the shaft collar. Bearings in which the thrust is always exerted in the same direction are equipped with shoes on one side only, but since provision must be made in most marine applications for thrust in two directions, it is more common to find shoes on each side of the collar. The shoes are free to adjust themselves at an angle to the collar. Rotation of the shaft collar drags a film of oil into the space between the shoes and the collar, and as the oil film forms, the shoes adjust themselves to the angle most efficient for the load conditions and the oil viscosity.

Additional information on Kingsbury-type thrust bearings and other types of bearings is provided in the *NAVSHIPS Technical Manual*, chapter 243. Detailed information on allowable tolerances and procedures for taking thrust bearing readings can be obtained from the manufacturer's technical manual.

End play checking of a Kingsbury thrust bearing must always be done with the upper half of the housing solidly bolted down, otherwise the base rings may tilt and provide a false reading.

Keep a record of the end play measurements and refer to them when checking the main thrust bearing. The normal wear of a pivoted shoe-type thrust bearing is negligible even with years of use. However, when a thrust bearing is new, there may be slight settling of the leveling plates. If you notice any increase in the end play, examine the thrust shoe surfaces, and make all necessary repairs.

In most cases, the main thrust bearing cap must be removed for inspection. The opening is of such size that it will permit the withdrawal of the pair of ahead and astern thrust shoes located in line with it.

CHECKING END PLAY WHILE RUNNING THE SHAFT.—The simplest method of checking end play is to use a suitable measuring instrument on any accessible part of the propeller shaft while running the shaft slowly ahead and astern. This is normally done at the end of a run when the ship is maneuvering to approach the pier before the machinery and shaft are cold. Although the speeds should be slow to avoid adding deflections of bearing parts and housing to the actual end play, these speeds should be sufficient to overcome the rake of the shaft and to ensure that the full end play is actually taken up.

End play is measured with a dial indicator mounted on a rigid support close to any convenient coupling flange. Occasionally a shaft may have a shoulder turned on it for the sole purpose of applying a dial indicator. Make sure that the flange surface is free from paint, burrs, and rust spots. The flange surface should also be well oiled in order to prevent damage to the dial indicator.

JACKING ON THE SHAFT FLANGE.—If it is not feasible to measure the end play of a shaft while running, your next choice is to jack the shaft fore and aft at some convenient main shaft flange.

Use a dial indicator make certain that the shaft movement is free, and guard against overdoing the jacking force. The main difficulty associated with the use of the jacking methods is in finding suitable supports to ensure that no structural damage will be incurred when jacking is done against a main shaft flange coupling.

MAIN PROPULSION SHAFT BEARINGS

You will be required to watch and maintain the main propeller shaft bearings. These bearings support and hold the propulsion shafting in alignment. They are divided into two general groups: the main line shaft bearings (spring bearings), and the stern tube and strut bearings.

MAIN LINE SHAFT BEARINGS (SPRING BEARINGS)

The main line shaft bearings (spring bearings) are of the ring-oiled, babbitt-faced, spherical seat, shell type. These bearings (figure 4-3) are designed primarily to align themselves *to* support the weight of the shafting. In many of the older, low-powered ships, the bearings are not of the self-aligning type and consist only of bottom halves. The upper half of each assembly consists only of a cap or cover (not in contact with the shaft) designed to protect the shaft journal from dirt. The spring bearings of all modern naval ships, however, are provided with both upper and lower self-aligning bearing halves.

The brass oiler rings (figure 4-3) hang loosely over the shaft journal and the lower bearing half, and are slowly drag fed around by the rotation of the shaft. The upper half of the bearing is

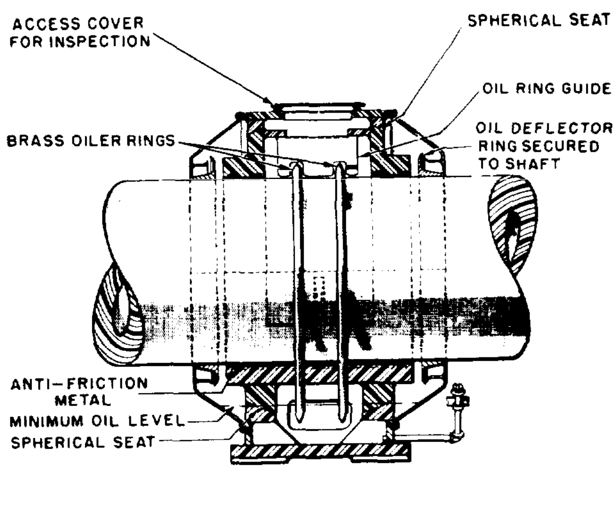

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Figure 4-3.—Main line shaft bearing.

grooved to accommodate the rings. As they glide through the reservoir of oil at the bottom, the rings carry some of the oil along to the top of the shaft journal.

On some steam driven ships, the most recent line shaft bearing design employs oiler discs instead of oiler rings for lubrication. At very low speeds (i.e., when the shaft is jacked for 24 hours while the turbines are cooling), the oil rings tend to slip and lubrication is sometimes inadequate. The oiler discs are clamped to propulsion shaft and have cavities at the periphery which carry oil to the top of the bearing regardless of the shaft speed.

Spring bearing temperatures and oil levels should be checked hourly while underway. At least once each year, the bearings should be inspected, clearances taken, and any defects corrected.

STERN TUBE AND STERN TUBE BEARINGS

The hole in the hull structure for accommodating the propeller shaft to the outside of the hull is called the stern tube. The propeller shaft is supported in the stern tube by two bearings—one at the inner end and one at the outer end of the stern tube—called stern tube bearings. At the inner end of the stern tube there is a stuffing box containing the packing gland (figure 4-4), which is generally referred to as the stern tube gland. The stern tube gland seals the area between the shaft and stern tube but allows the shaft to rotate.

The stuffing box is flanged and bolted to the stern tube. Its casing is divided into two compartments—the forward space which is the stuffing box proper, and the after space, provided with a flushing connection, designed to maintain a positive flow of water through the stern tube for lubricating, cooling, and flushing. This flushing connection is supplied by the firemain. A DRAIN CONNECTION is provided both for testing for the presence of cooling water in the bearing and for permitting sea water to flow through the stern tube and cool the bearing when underway, where natural seawater circulation is employed.

The gland for the stuffing box is divided longitudinally into two parts. The gland bolts are long enough to support the gland when the latter is withdrawn at least 1 inch clear of the stuffing

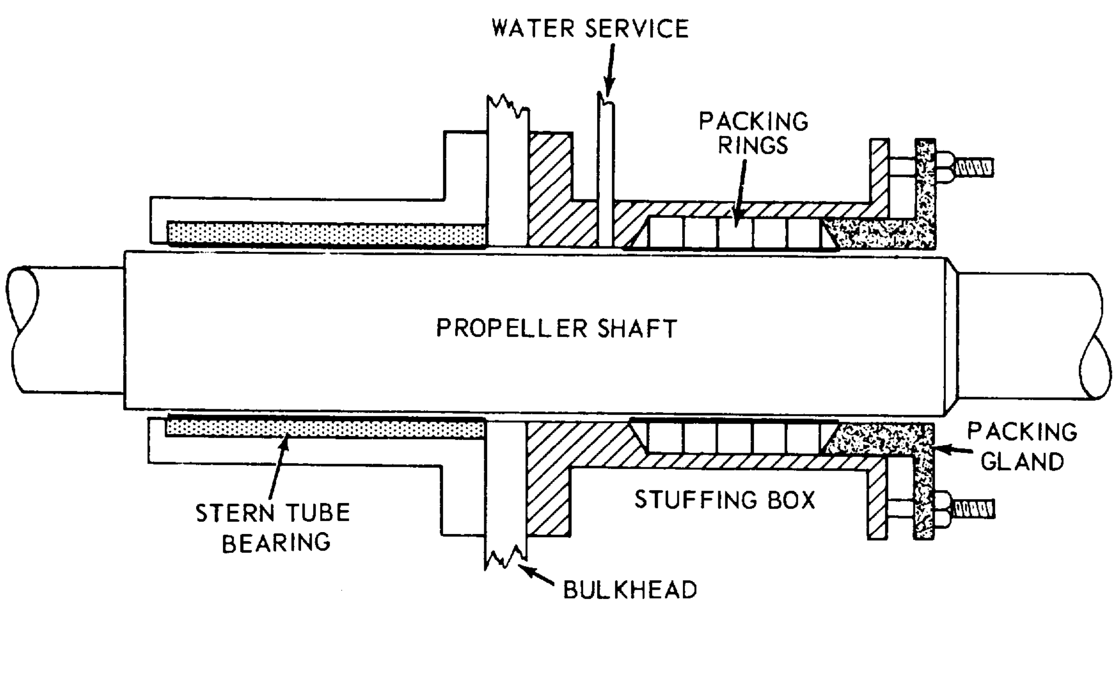

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Figure 4-4.—Stern tube stuffing box and gland.

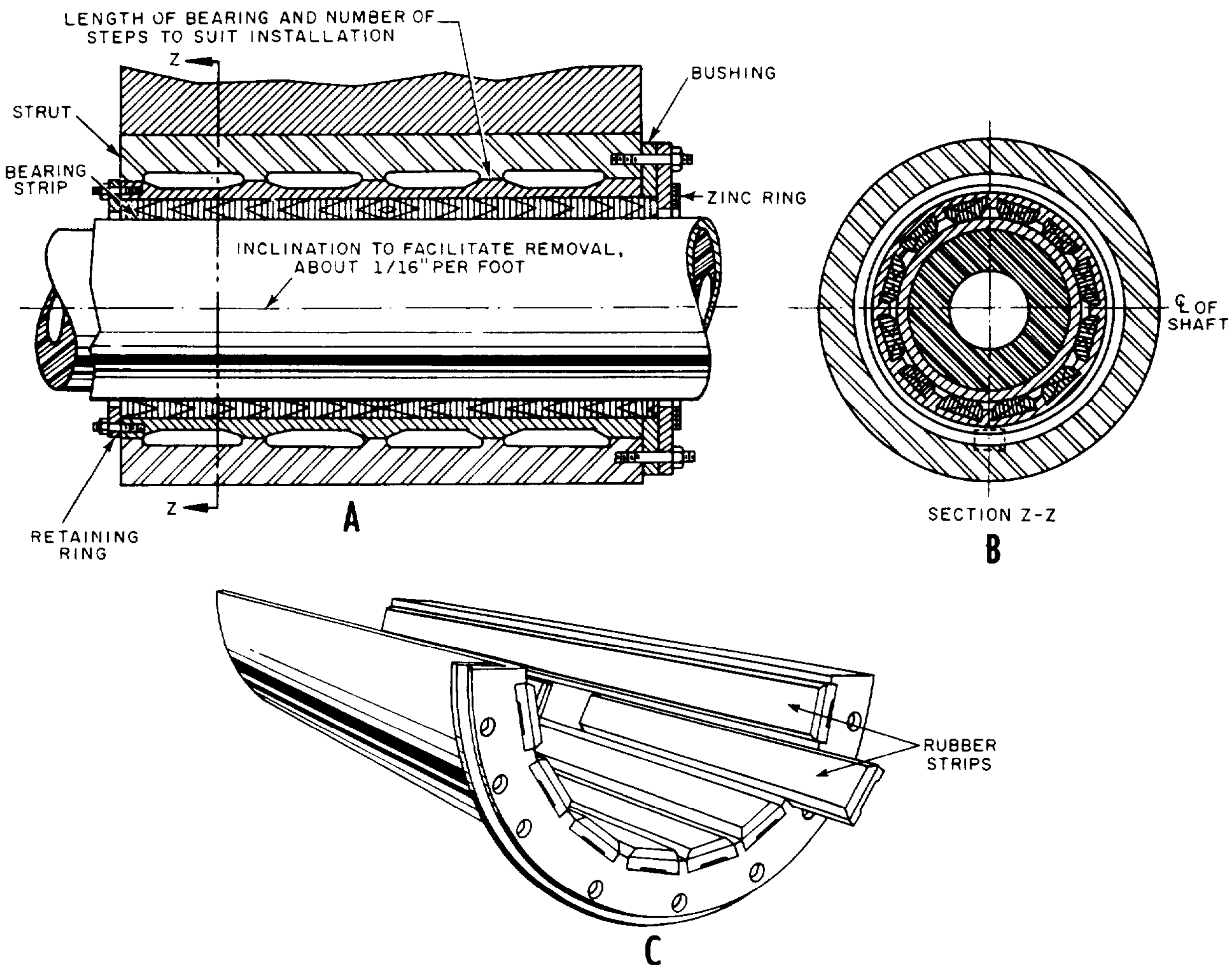

Figure 4-5.—Details of underwater strut bearing. A. Longitudinal view. B. Cross-sectional view. C. Rubber stripping in the bearing.

box. This permits the addition of a ring of new packing, when needed, while the ship is waterborne. Either braided flax packing or special semimetallic packing must be used (ship's engineering drawings show the proper type of packing). This gland is usually tightened to eliminate leakage when the ship is in port, and is loosened (prior to warming up) just enough to permit a slight trickle of water for cooling purposes when the ship is underway.

More recent shaft seal designs utilize packing only for emergencies. These newer seals are of two types; rubber face seals and mechanical face seals. Both face seals are on a plane perpendicular to the shafting, against a gland ring for rubber face seal or against a seal ring for a mechanical face seal. Further, most face seals require seawater for both cooling and lubrication.

The rubber face consists of a rubber element that is clamped around the shaft just tightly enough to prevent rotational slippage and leakage underneath the seal, while at the same time, the seal is able to travel axially along the shaft. This axial motion is necessary so that the seal can maintain its position against the gland ring regardless of shaft position.

The mechanical face seal is a ring made of either a hard synthetic or a carbon compound. This ring is held tightly against the seal ring by springs mounted behind it.

NOTE: More information on face-type seals is available in manufactures technical manuals—(Crane Co., *"Surface Ship, Seal Inc.", "Submarine").*

STRUT BEARINGS

The strut bearings, like the stern tube bearings, are equipped with composition bushings which are split longitudinally into two halves. The outer surface of the bushing is machined with steps to bear on matching landings in the bore of the strut.

Since it is usually impracticable to use oil or grease as a lubricant for underwater bearings, some other material must be employed for that purpose. Materials that become slippery when wet include natural or synthetic rubber; lignum vitae, a hard tropical wood with excellent wearing qualities; and laminated phenolic material consisting of layers of cotton fabric impregnated and bonded with phenolic resin. Strips of this material, as shown in view C of figure 4-5, are fitted inside the bearing. A rubber composition is the type most used in modern installations.

CONTROLLABLE PITCH PROPELLERS

This section will describe the major components and the principles of operation of the controllable reversible pitch (CRP) propeller (a part of the main propulsion system).

COMPONENTS OF THE CRP PROPELLER

Most ships that use CRP propellers use two independent units with their associated mechanical, hydraulic, and electronic pitch control mechanisms, plus all the required valves and seals. Some type ships require tubing and passages for the discharge of prairie air through each propeller blade. The CRP propellers form an integral part of the ship's two shaft main propulsion system. Figure 4-6 shows the major components of a single CRP propeller.

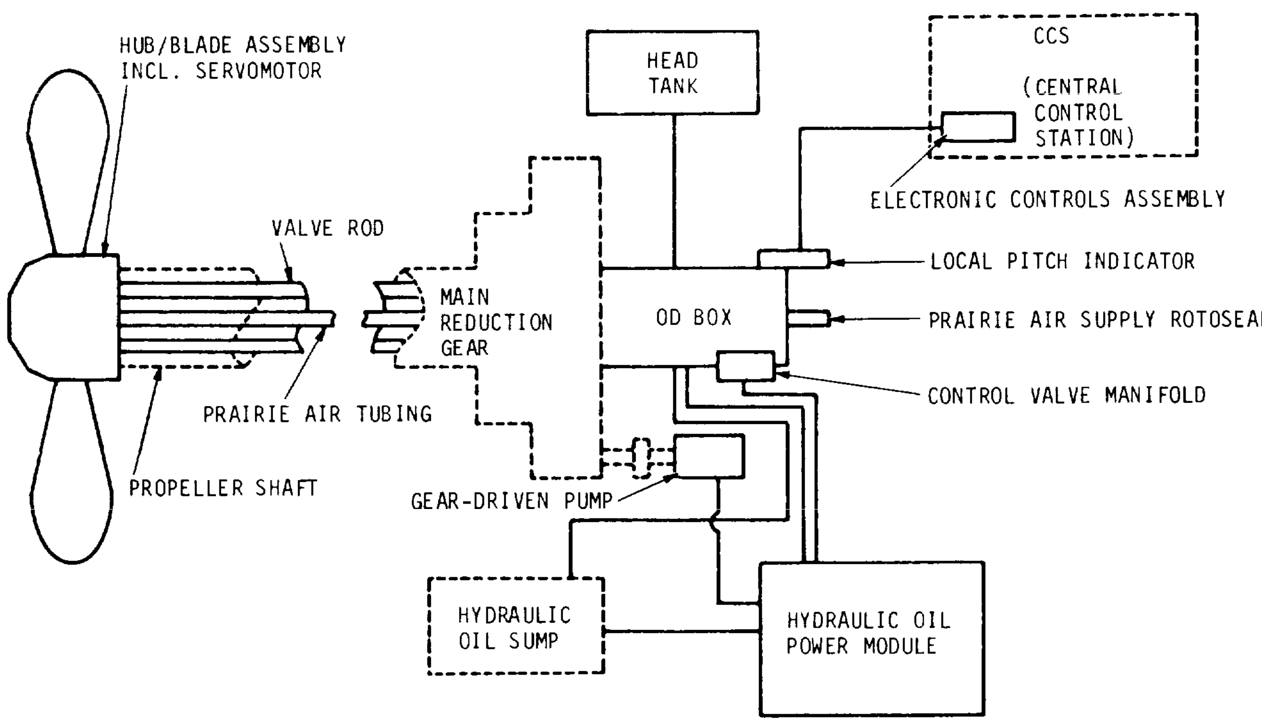

Figure 4-6.—CRP Propeller Machinery.

Table 4-1.—Related Propulstion System Components

System Name/Description
Main Reduction Gear, Mounting and Coupling for Gear-Driven Hydraulic Oil Pump.
Propeller Shaft.
Interconnecting Hydraulic Oil Piping.
Head Tank, Sump Tank and Hydraulic Oil Supply plus Associated Components, and Fittings.
Central Control Station (CCS) Controls and Indicators.

Related propulsion system components, which are necessary for the operation of a CRP propeller but which are not part of the CRP propeller are listed in table 4-1. Let's look at some of these components, along with other components, shown in table 4-2.

Hub/Blade Assembly

The propeller's hub/blade assembly (see figure 4-6), attached to the main propulsion propeller shaft, provides the mounting for the propeller blades and houses the blade turning mechanism for rotating and holding the pitch position of the blades. Attached to the after end of the hub body are the hub cone and the hub cone end cover. These items form the chamber for the servomotor piston. The hub body is fitted to the tailshaft by guide pin dowels which also transmit the torque

Table 4-2.—CRP Propeller Hardware Components

HUB BLADE ASSEMBLY Hub Assembly, LG Hub assembly. RH Blades (Set of 5). LH Blades (Set of 5). RH VALVE ROD ASSEMBLY Piping, Couplings & Guides, Port Piping, Couplings & Guides, Stbd OIL DISTRIBUTION BOX DD Box Assembly. Port DD Box Assembly, Stbd.	HYDRAULIC SYSTEM Hydraulic Oil Power Module, P/S (each including): Suction Strainer (1) Hydraulic Oil Pump, Coupling and Motor (1) Duplex Discharge Filters (3) Air Bleed Valves (2) Pressure Control Assembly, consisting of: sequence and relief valve, unloading and check valve, reducing Valve, and control oil relief valve. Manual Bypass Valve (1) Gauge Panels (2) Manifold Block Assembly, P/S (each including): Electra-hydraulic Servo Control Valve (1) Manual Pitch Control Valve (1) Manual Changeover Valves (2) Standby Hydraulic Oil Pump (gear driven), P/S Suction Strainer (gear pump), P/S Return Check Valve, P/S	ELECTRONIC PITCH CONTROL SYSTEM Electronic Pitch Control Assembly, P/S Feedback Potentiometer, P/S Readout Potentiometer, P/S LOCAL PITCH INDICATOR Pitch Indicating Assembly, P/S EMERGENCY PITCH SETTING Emergency Hand Pump Assembly, P/S PRAIRIE AIR SYSTEM Rotoseal, P/S Check Valve (hub), LH/RH Check Valve (OD Box), P/S Prairie Air Tube Assy.. P/S Connectors, Prairie Air, Hub to Blade (Set of 5). LH/RH

from the shafting to the hub assembly. The hub is secured to the tailshaft by flange bolts. These bolts are not designed to take torque from the tail shaft. The hub to tailshaft joint is sealed by O-rings located between the hub and the tailshaft, and between the tailshaft and the tailshaft spigot. Each blade is attached to a crank pin ring by blade bolts. The crank pin ring fits over and rotates about a center post which is physically a part of the hub body. The crank pin ring is retained in the hub by the bearing ring. The area under each blade is sealed by the blade port cover and by two O-rings in the blade seal base ring. Each blade seal base ring is spring-loaded against the underside of the blade port cover to provide a sealing surface under all loading conditions.

The blade turning mechanism in the hub consists of a single crosshead, attached to the end of a piston rod. Several sliding blocks are fitted into the machined chambers of the crosshead. An eccentric pin on the underside of each crank pin ring fits into a hole machined into each sliding block. The hub servomotor is attached to the after end of the crosshead. A piston rod carries the lines for the regulating valve pin which is attached to the end of the valve rod. This assembly forms a passage for hydraulic power oil flow and return oil flow to and from the hub.

Valve Rod Assembly

The valve rod assembly is composed of fabricated sections of seamless steel tubing joined by couplings to provide a mechanical link between the oil distribution (OD) box and the hub servomotor through the internal bore of the propeller shaft. The valve rod assembly provides a passage for high pressure hydraulic oil from the oil distribution box to the hub. Each valve section is supported at the center of the propeller shaft bore by guides. The after end of the valve rod assembly supports a regulating valve pin which operates in the valve pin liner of the hub servomotor. The forward end of the valve rod assembly is mechanically linked to the OD box shaft, so that the valve rod assembly turns with the shaft.

Oil Distribution Box

Presently there are two types of OD boxes being used in the Navy. One type, used on FFG-7 class and DD 963 class ships, is mounted to the forward end of the main reduction gear and is flange-connected to the main reduction gear shaft coupling. The other type, used on the LST 1179-1198 class ships, is called the Bird-Johnson Kamewa Unit; it is manufactured of steel, is cast in two sections, and is line-bored for installation over the intermediate shaft. The OD box provides a direct hydraulic oil connection to the main propulsion shaft and also translates to the valve rod in response to hydraulic control oil commands. High pressure oil from the hydraulic oil power module (HOPM) is introduced through the OD box to the internal bore of the valve rod and to the hub. The oil returns from the propeller hub to the hydraulic oil sump tank by way of the annulus between the valve rod and the internal bore of the shafting, through the OD box.

Hydraulic System

The hydraulic system consists of a self-contained HOPM, a standby hydraulic pump driven by the main reduction gear, the pitch control valves manifold block assembly, and all the associated connecting piping, fittings, and valves. The hydraulic oil is supplied to the hydraulic oil pumps from a separate sump tank. To maintain a static head pressure when the hydraulic system is shut down, a gravity head tank is connected to the OD box.

HYDRAULIC OIL POWER MODULE.—The HOPM is located adjacent to the main reduction gear. It is a RESILIENT mounted, welded structural assembly, consisting of a base plate with structural ANGLE bar, flat bar, and mounting plates. The HOPM contains the major components of the hydraulic system, including (1) either the motor-driven hydraulic screw or the vane pump, coupling, and AC motor; (2) a suction strainer for the motor-driven pump; (3) two 40 micron duplex discharge filters; (4) the pressure control assembly operating valves, which consist of a pressure reducing valve, an auxiliary relief valve, a check valve, an unloading and check valve, and a relief and sequence valve; (5) one 10 micron duplex control oil filter; (6) a gauge panel assembly and associated instrumentation; (7) a manual bypass valve; and (8) the interconnecting piping and fittings.

STANDBY PUMP.—The standby pump is of the same type as the main hydraulic pump, but it is mounted at the forward end of the main reduction gear housing and is driven through a disconnect coupling. The suction strainer and suction gauge for this pump are mounted separately. The primary function of the standby pump is to assist the main pump in effecting pitch changes. When the control pitch (C/P) unit is in the holding pitch position, the standby pump discharge oil is unloaded back to the sump through the hydraulic block. But, whenever a pitch change is ordered, the pump discharge oil is directed to the hydraulic block high pressure passage.

LOWER OIL TANK.—The lower (sump) oil tank is usually located aft and below the OD box assembly. The oil capacity of the sump varies depending on the type and class of ship. Two pumps, the main and standby hydraulic pumps, take suction on the lower oil tank through a foot valve, which permits the oil to flow from the tank but does not allow it to return through the suction line.

UPPER GRAVITY OIL TANK.—This tank is located above the maximum draft line. Its main purpose is to maintain hub oil pressure above that of the surrounding seawater when the C/P unit is secured. In the Kamewa installation, the upper gravity oil tank serves an additional purpose. During C/P unit operation the tank assists in maintaining the sliding ring chamber pressure.

PRINCIPLES OF OPERATION

The CRP propeller provides the ahead and astern propulsion thrust for a vessel by a change in the pitch of the propeller blades. Such changes can be obtained even when the main propulsion machinery, including the propeller shaft, are turning at a high rate of speed. Blade pitch control permits a full range of ahead and astern thrusts. Maximum ahead thrust is provided with the blades in the full ahead pitch position, and maximum astern thrust is provided with the blades in the full astern pitch position. When the propeller blades are set at zero thrust, the propeller shaft may be turning at any speed without imparting thrust to the vessel.

When a change of propeller pitch position is ordered, a pitch position command from the propulsion control system is fed to the controls. This command signal activates the electrohydraulic servocontrol valve which, in turn, activates the flow of control oil to and from the OD box to change the position of the valve rod actuator. The hydraulic power oil flows to the OD box and is admitted to the valve rod via the annular chamber in the OD box and the ports in the valve rod. The oil flows within the bore of the valve rod to the hub servomotor, and returns from the hub via a passage formed between the valve rod and the propulsion shaft bore. ‘The oil leaves the OD box via ports in the OD box shaft and the annular chamber to return to the sump tank. Control oil is regulated by a set of sequencing and reducing valves in the hydraulic system which maintain the required pressure level. Control oil is supplied to the electrohydraulic servocontrol valve. From the servocontrol valve, the control oil flows to one side of the low pressure (LP) chamber of the OD box to drive the valve rod actuator. Control oil returns to the sump through the OD box manifold from the other side of the LP chamber.

When the propeller is operating at the desired blade pitch position, the OD box valve rod actuator is hydraulically locked and the hub servomotor is hydraulically held in a stationary position. The configuration of the regulating valve pin in the hub servomotor allows hydraulic power oil to circulate continuously through the hub servo. The oil pressure developed on each side of the hub servomotor piston is balanced and established at the level necessary to counteract blade loading which would tend to change pitch position. A hydraulic pitch change signal from the electrohydraulic servo control valve moves the valve rod actuator and the valve rod. This movement changes the size of the oil passages to each face of the hub servomotor piston, thereby creating a differential pressure in the circulating oil to each face of the piston. The regulating valve pin then supplies high pressure oil to one face of the piston and connects the other face to the return oil passage. The high pressure oil develops the necessary pressure on the piston face to overcome blade loading and move the turning mechanism and the blades to the desired pitch position. Blade pitch will continue to change until the oil port openings equalize and the oil pressure developed on each face of the piston is balanced. Removing the oil signal from the valve rod actuator stops motion in the valve rod and the hub servomotor. The self-centering feature of the servomotor over the regulating valve pin provides the restoring force to counteract any hydrodynamic tendency to change pitch from that set by the command signal.

INSPECTIONS

The inspections mentioned here are the minimum requirements for reduction gears. Where defects are suspected, or operating conditions so indicate, inspections should be made at more frequent intervals.

No inspection plates or other fittings of the main reduction gear may be opened without the permission of the engineer officer. Before replacing of an inspection plate, connection, fitting, or cover which permits access to the gear casing, make a careful inspection to ensure that no foreign matter has entered or remains in the casing or oil lines. An entry of the inspections, and the name of the CPO or officer who witnesses the closing of the inspection plate, should be made in the Engineering Log.

PMS INSPECTIONS

The PMS requirements discussed in this section are general in scope. Inspection requirements for your ship are listed in the ship's PMS Manual and should be referred to for all maintenance action.

Gears should be jacked DAILY—AT ANCHOR—so that the main gear shaft is moved 1 1/4 revolutions. This jacking should be done with lubricating oil circulating in the system.

You should take the following actions QUARTERLY:

1. Sound with a hammer the holding down bolts, ties, and chocks to detect signs of loosening of casing fastenings.
2. Open inspection plates, inspect gears, and oil-spray nozzles. Wipe off oil at different points and note whether the surface is bright or if already corroded, and whether or not new areas are affected.
3. Inspect the strainers for the oil-spray nozzles to see that dirt or sediment has not accumulated in them.
4. Take and record all main thrust bearing readings.

When conditions warrant or if trouble is suspected, a work request should be submitted to a naval shipyard to perform a 7-YEAR INSPECTION of the main reduction gears. This inspection includes clearance readings of bearings and journals; alignment checks and readings; and any other inspections, tests, or maintenance work that may be considered necessary.

If the ship's propeller strikes ground or a submerged object, a careful inspection should be made of the main reduction gear immediately following the OCCURRENCE of the casualty. In this inspection, the possible misalignment of the bull gear and its shaft should be considered. Where practicable, a naval shipyard should be requested to check the alignment and concentricity of the bull gear.

NAVAL SHIPYARD OVERHAUL

During a naval shipyard overhaul, the following work should be performed: inspection of the condition and clearance of thrust shoes to ensure proper position of gear; inspection of the thrust collar, nut, and locking device; and inspection of the flexible couplings between turbines and reduction gears and removal of the sludge deposits.

FULL POWER TRIALS

The correction of any defect disclosed by regular tests and inspections, and the conscientious observance of the manufacturers' instructions, should assure that the gears are ready for full power at all times.

It is not advisable to open up gear cases, bearings, and thrusts immediately BEFORE TRIALS. In addition to the inspections which may be directed by proper authority which are conducted during the FULL POWER TRIALS, the following checks must be made AFTER TRIALS. Open the inspection plates, and examine the tooth contact and the condition of the teeth to note changes that may have occurred during the trials. (Running for a few hours at high power will show any possible condition of improper contact or abnormal wear that would not have shown up in months of operation at lower powers.) Check the clearance of the main thrust bearing.

SAFETY PRECAUTIONS

Observe the following safety precautions which apply to the operation, care, and maintenance of reduction gears and related equipment found on Navy ships.

1. If churning or emulsification of the oil in the gear case occurs, the gear must be slowed down or stopped until the defect is remedied.
2. If the supply of lubricating oil to the gears fails, the gears should be stopped and the cause located and remedied.
3. When bearings have been overheated, the gears should NOT be operated—except in extreme emergencies—until bearings have been examined and defects have been remedied.
4. If excessive flaking of metal from the gear teeth occurs, the gears should not be adjusted, except in case of emergency, until the cause has been determined.
5. Unusual noises should be investigated at once, and the gears should be operated cautiously or stopped until the cause for the noise has been discovered and remedied.
6. No inspection plate, connection, fitting, or cover which permits access to the gear casing should be removed without specific authority of the engineer officer.
7. The immediate vicinity of an inspection plate joint should be kept free from paint and dirt.
8. When gear cases are open, precautions should be taken to prevent the entry of foreign matter. The openings should never be left unattended unless satisfactory temporary closures have been installed.
9. Lifting devices should be inspected carefully before being used and should not be overloaded.
10. Naked lights should be kept away from vents while gears are in use (the oil vapor may be explosive).
11. Ships anchored in localities where there are strong currents or tides should take precautions and lock the main shafts.
12. When divers are in the vicinity of the propeller, propeller shafts should be locked.
13. When a shaft is allowed to turn or trail, the lubrication system must be in operation.
14. The main propeller shaft must be brought to a dead stop position before an attempt is made to engage or disengage the turning gear.
15. When a main shaft is being locked, precautions must be taken to apply the brake quickly and securely.
16. Where there is a limiting maximum safe speed at which a ship can steam with a locked propeller shaft, this speed should not be exceeded.
17. When the main gears are being jacked over, precautions must be taken to see that the turning gear is properly lubricated.
18. Before the main engines are started, it should be definitely determined that the turning gear has been disengaged.